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(54) **TORQUE SENSOR AND METHOD OF MANUFACTURING THE SAME**

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(57) **ABSTRACT**

The torque sensor includes a plurality of coil units having a substantially cylindrical shape, the coil units including a plurality of detection coils arranged to face a magnetic characteristic change portion formed on a rotary shaft. The coil units include a first coil unit and a second coil unit, and the first coil unit and the second coil unit are disposed in the axial direction of the shaft. The first coil unit and the second coil unit are fixed in an integrally molded resin. Thereby, there is provided a torque sensor having a high productivity and an easy configuration and a method of manufacturing the torque sensor.

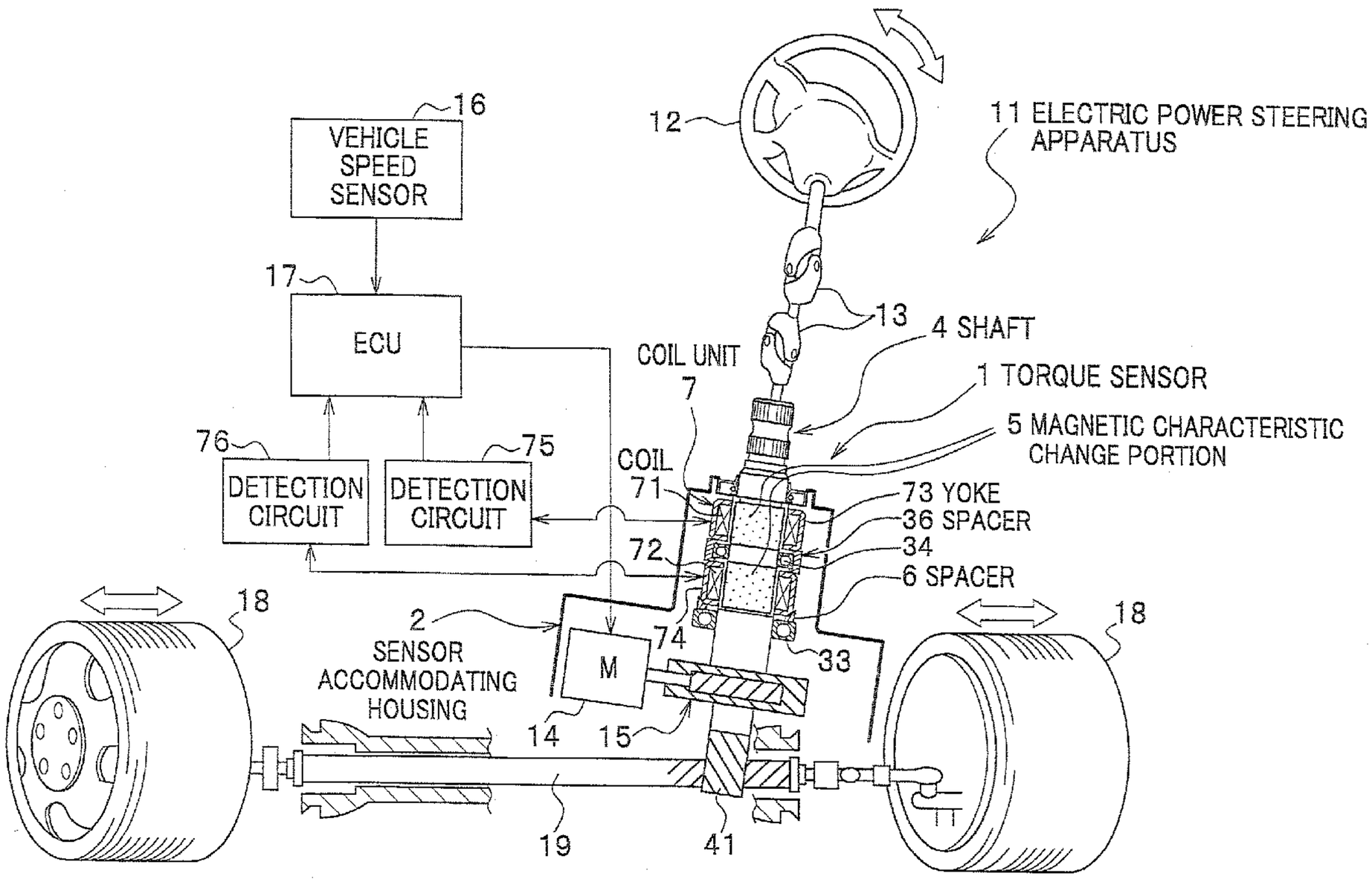


FIG. 1

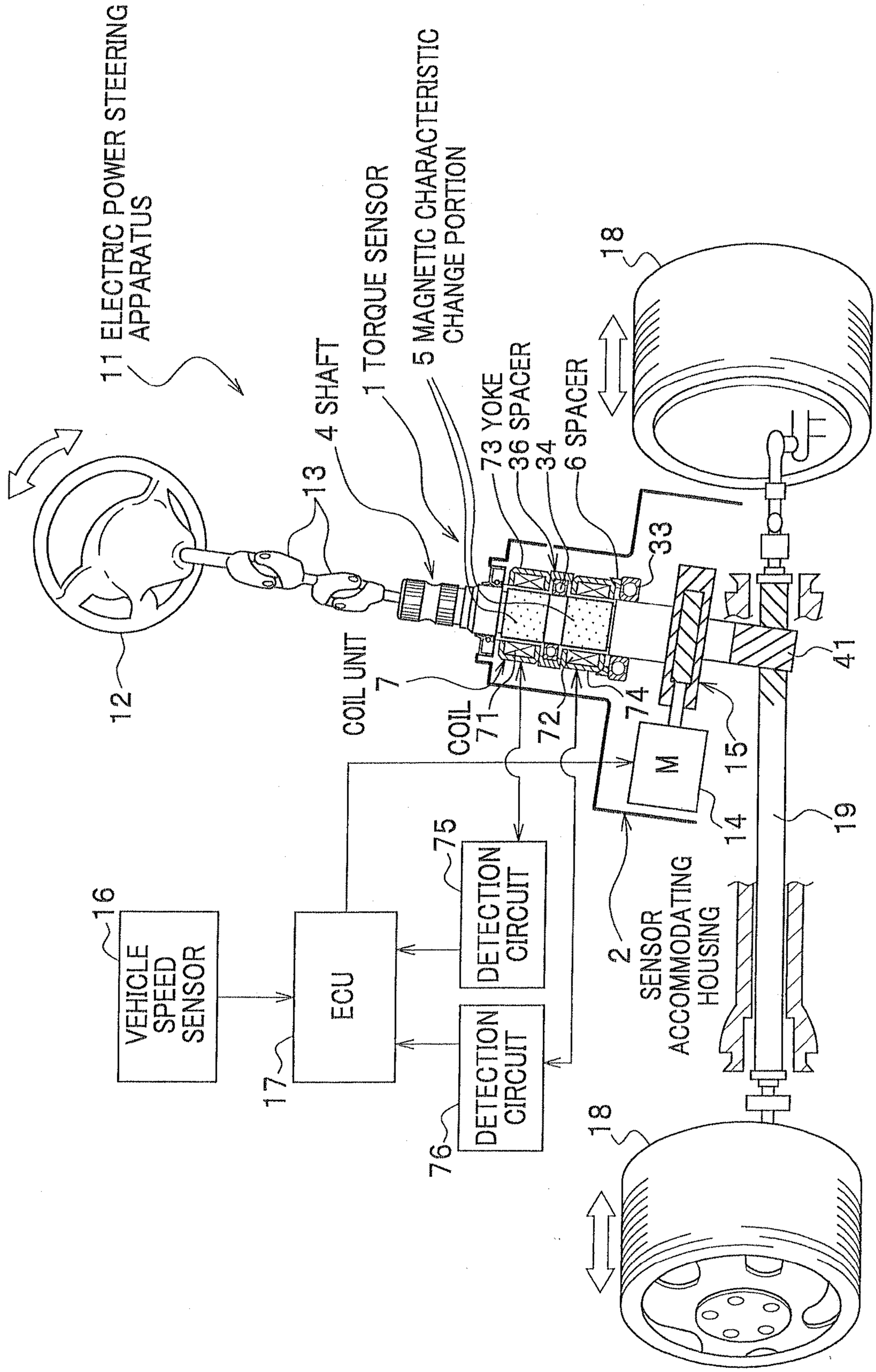

11 ELECTRIC POWER STEERING APPARATUS
1 TORQUE SENSOR
5 MAGNETIC CHARACTERISTIC CHANGE PORTION
4 SHAFT
13
12
73 YOKE
36 SPACER
34
6 SPACER
33
41
COIL UNIT
7
COIL
71
72
74
M
15
14
19
75
DETECTION CIRCUIT
16
VEHICLE SPEED SENSOR
ECU
17
DETECTION CIRCUIT
76
2
SENSOR ACCOMMODATING HOUSING
18

FIG.2

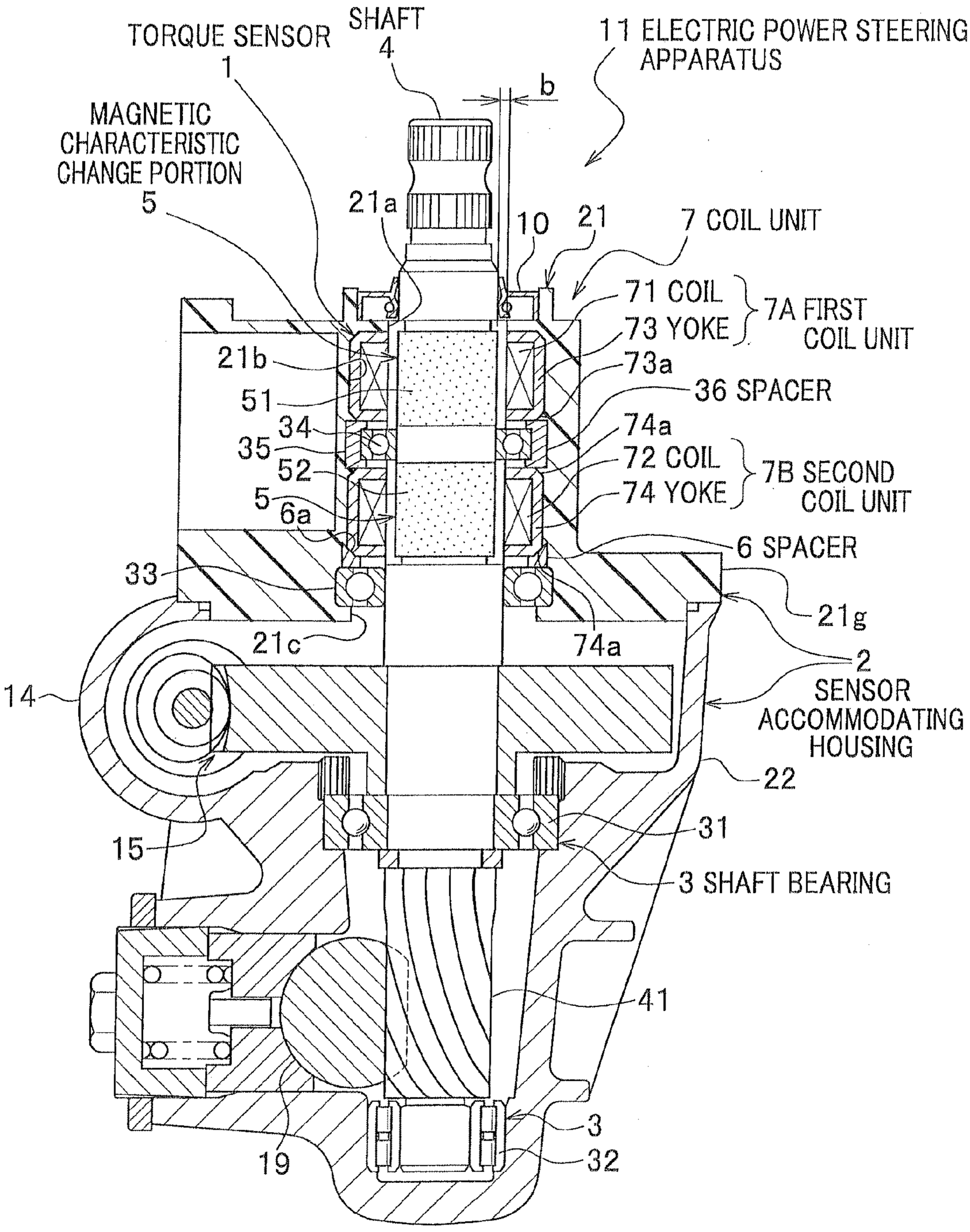

TORQUE SENSOR
1
SHAFT
4
11 ELECTRIC POWER STEERING APPARATUS
b
MAGNETIC CHARACTERISTIC CHANGE PORTION
5
21a
10
21
7 COIL UNIT
71 COIL
73 YOKE
7A FIRST COIL UNIT
21b
73a
51
36 SPACER
34
74a
35
72 COIL
74 YOKE
7B SECOND COIL UNIT
52
5
6a
6 SPACER
33
21g
21c
74a
2
SENSOR ACCOMMODATING HOUSING
14
22
31
15
3 SHAFT BEARING
41
3
19
32

FIG.3

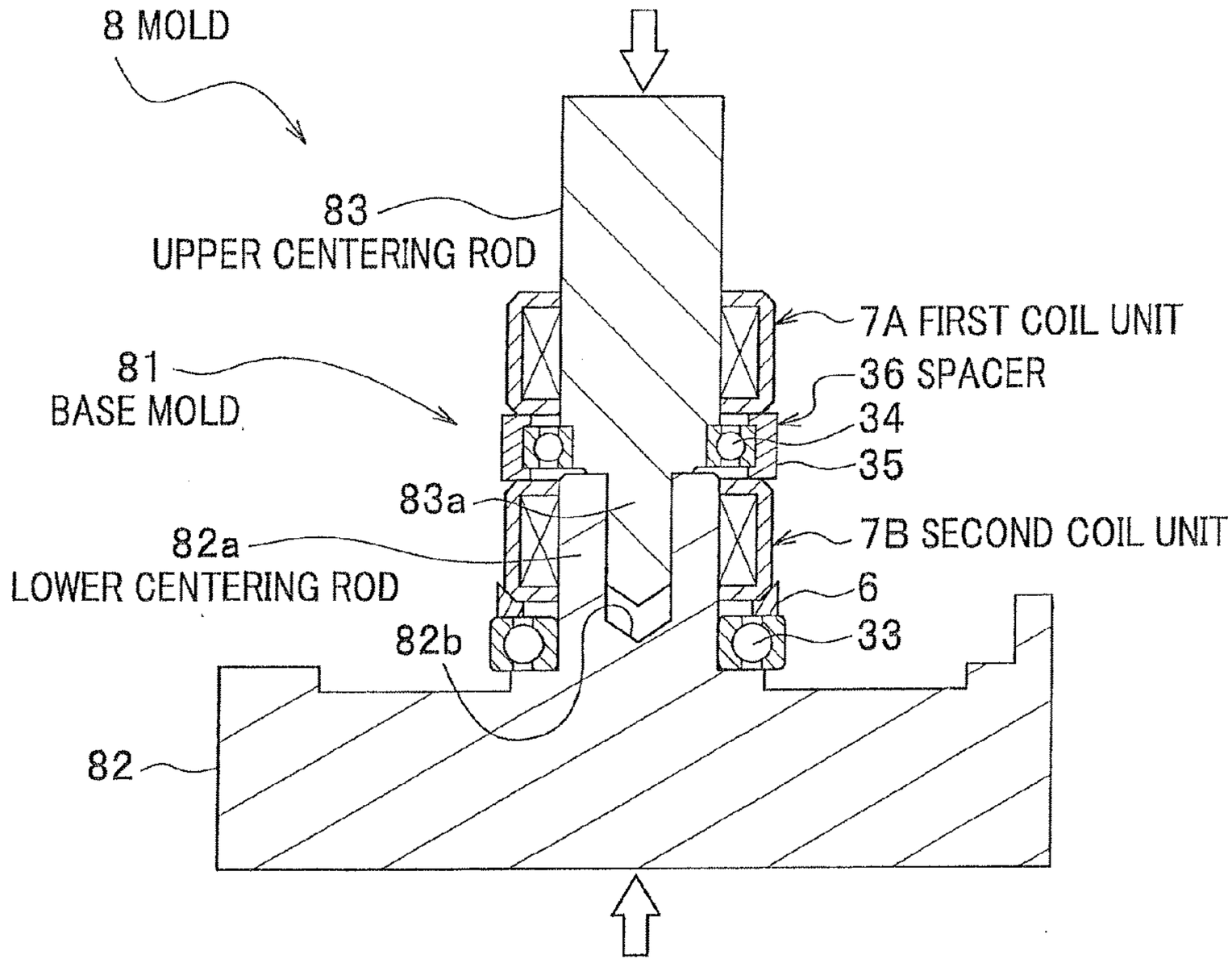

8 MOLD
83
UPPER CENTERING ROD
81
BASE MOLD
83a
82a
LOWER CENTERING ROD
82b
82
7A FIRST COIL UNIT
36 SPACER
34
35
7B SECOND COIL UNIT
6
33

FIG.4

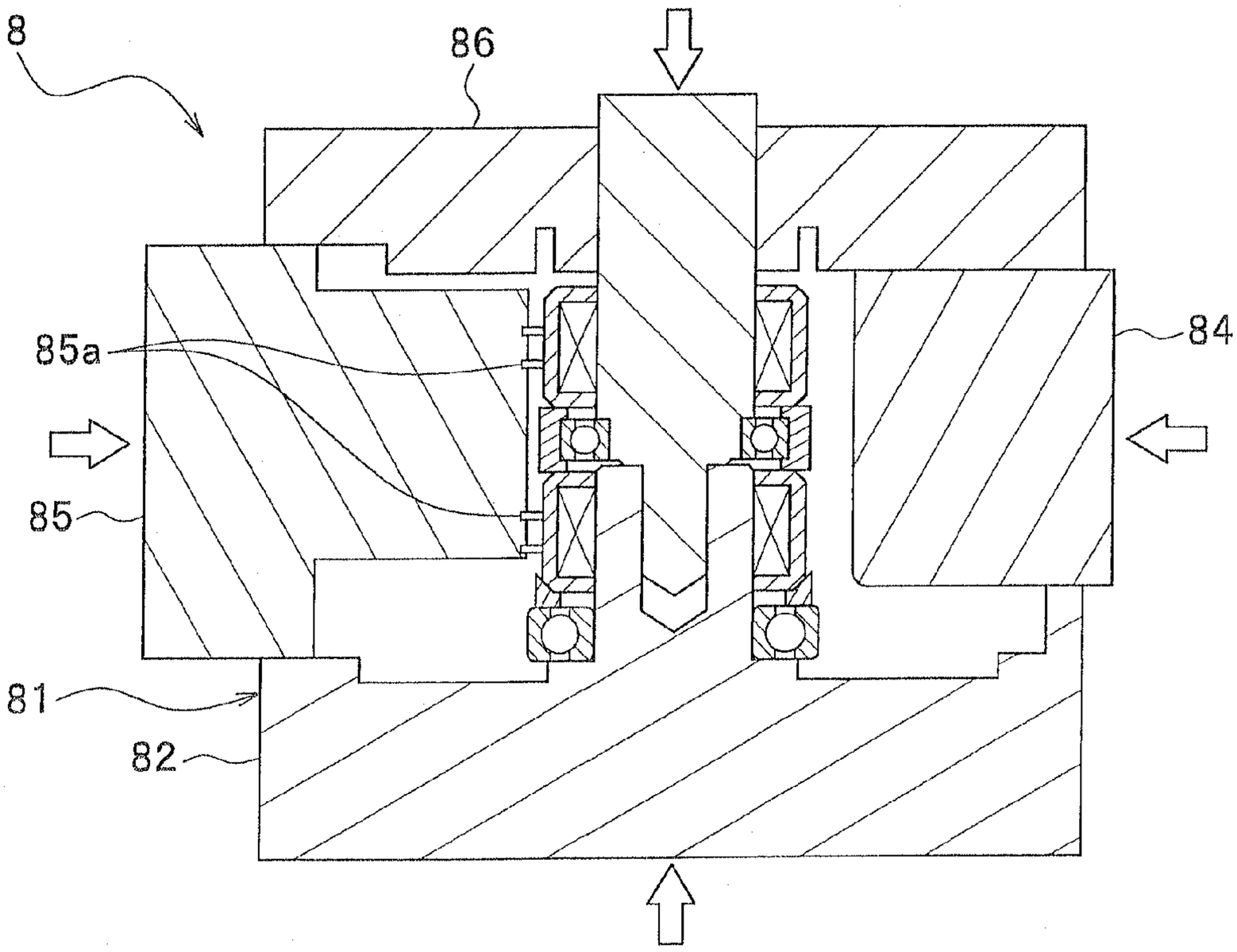

8
86
85a
85
81
82
84

FIG.5

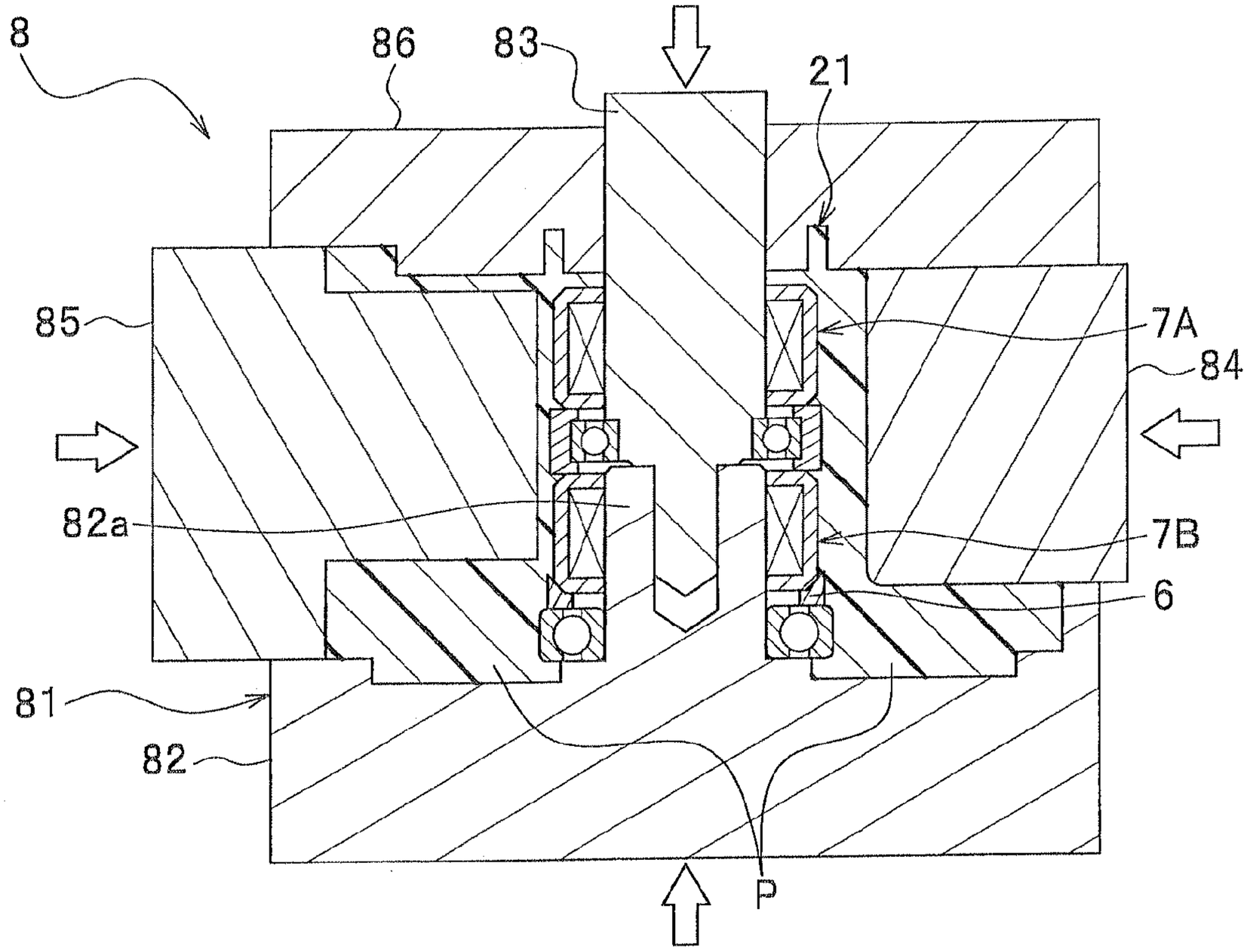


FIG.6

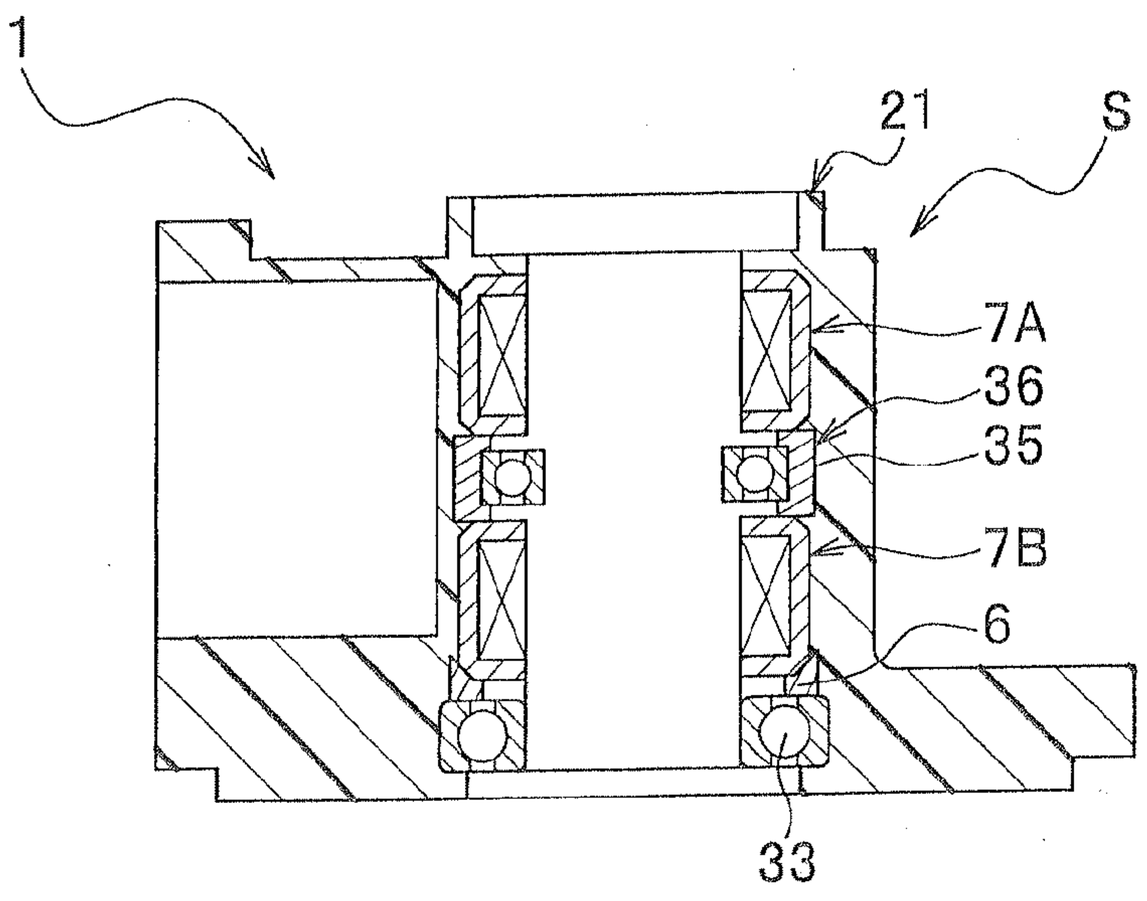


FIG.7

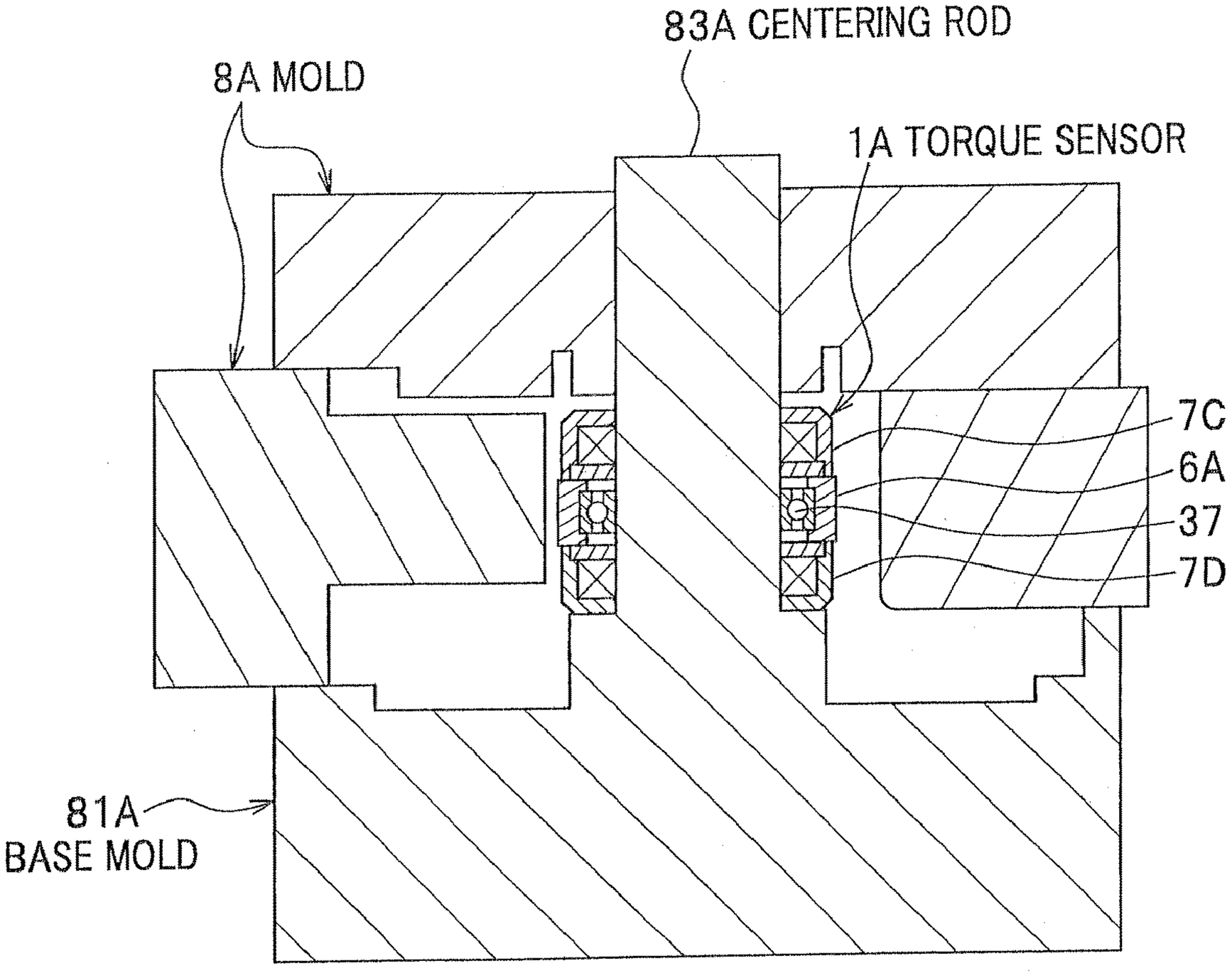

83A CENTERING ROD
8A MOLD
1A TORQUE SENSOR
7C
6A
37
7D
81A
BASE MOLD

FIG.8

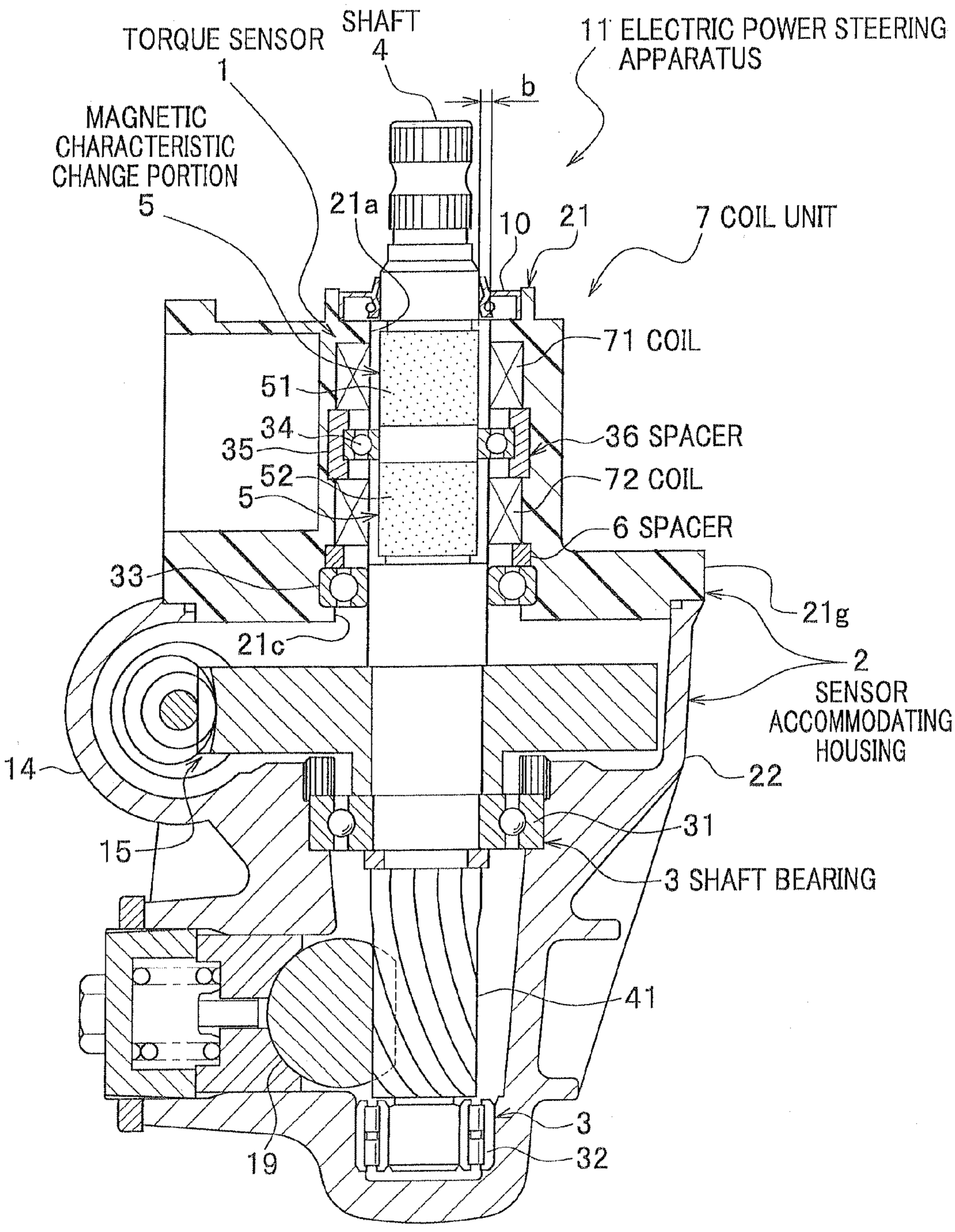

TORQUE SENSOR
1
SHAFT
4
11 ELECTRIC POWER STEERING APPARATUS
b
MAGNETIC CHARACTERISTIC CHANGE PORTION
5
21a
10
21
7 COIL UNIT
71 COIL
51
34
35
52
5
36 SPACER
72 COIL
6 SPACER
33
21g
21c
2
SENSOR ACCOMMODATING HOUSING
14
22
31
15
3 SHAFT BEARING
41
3
19
32

FIG.9
PRIOR ART

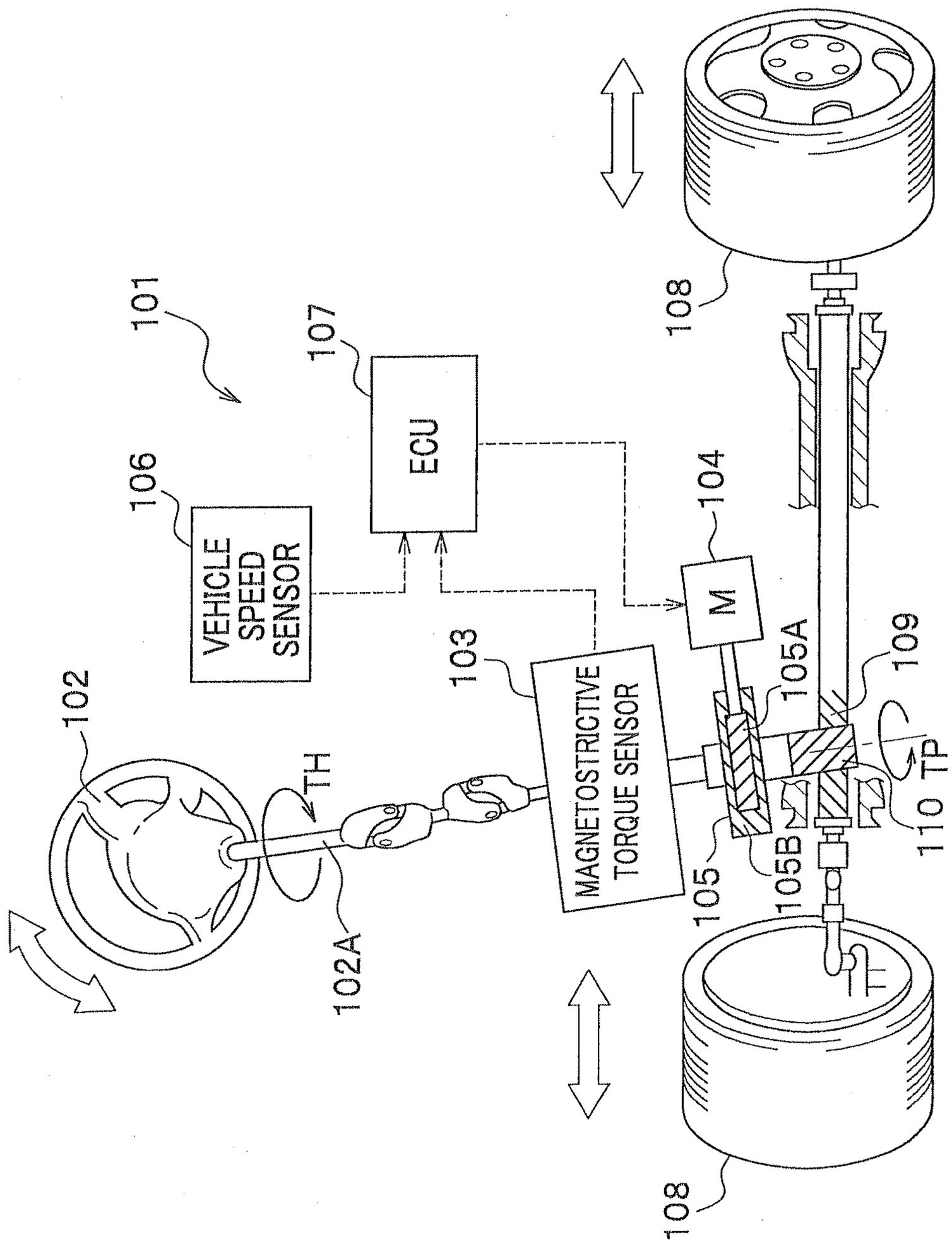
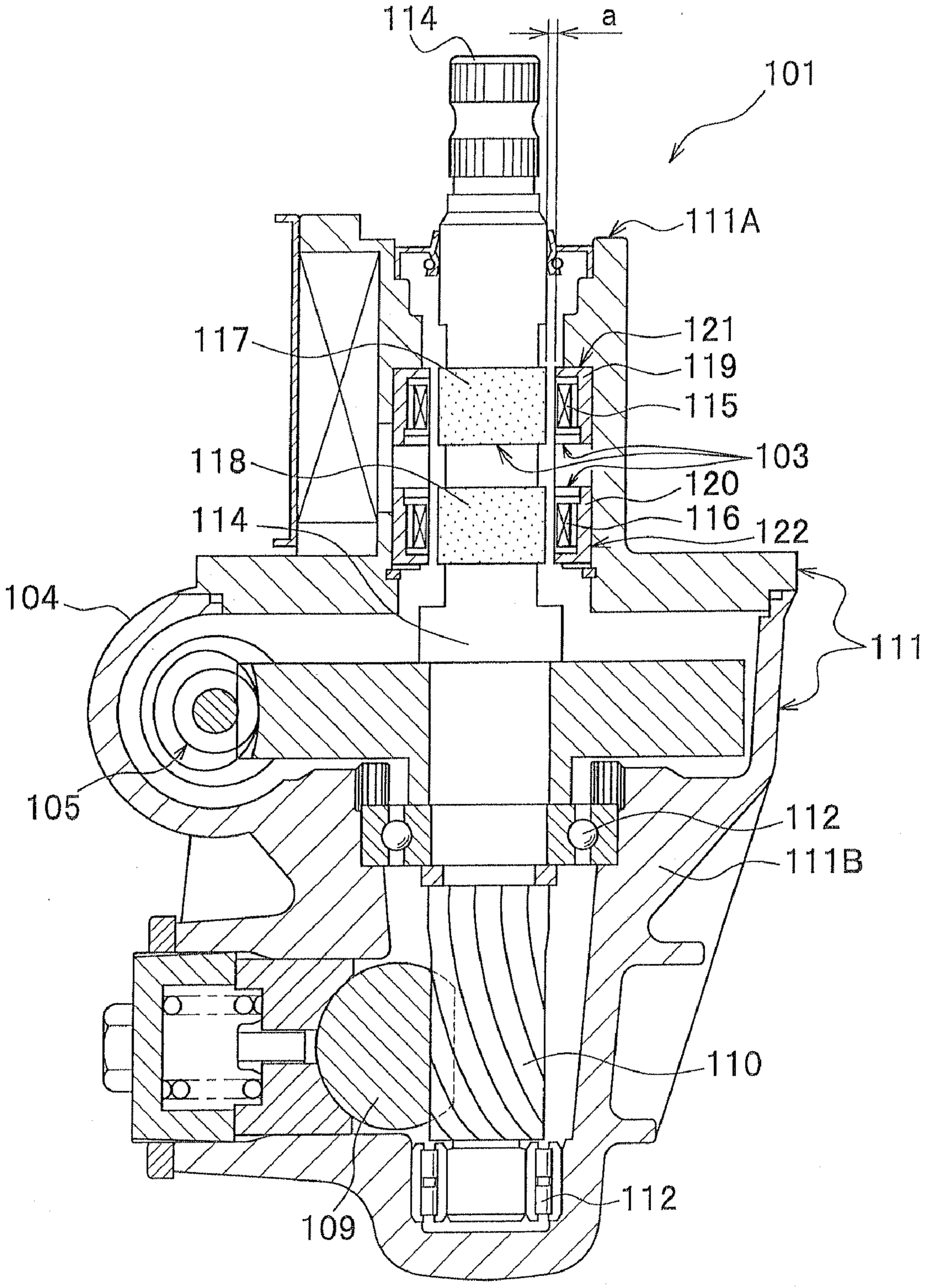


FIG.10
PRIOR ART



TORQUE SENSOR AND METHOD OF MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a divisional application of U.S. patent application Ser. No. 11/723,752, filed Mar. 21, 2007, now pending, which claims the foreign priority benefit under Title 35, United States Code, §119 (a)-(d), of Japanese Patent Applications No. 2006-87468 filed on Mar. 28, 2006 and No. 2007-22704 filed Feb. 1, 2007 in the Japan Patent Office, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates to a torque sensor and a method of manufacturing the same, and particularly to a torque sensor that is mounted in an electric power steering apparatus of a vehicle or the like, and is used as a detection device to magnetically detect steering torque applied to a shaft through a steering shaft, and a method of manufacturing the torque sensor.

[0004] 2. Description of the Related Art

[0005] In an electric power steering apparatus mounted in a vehicle, generally a torque sensor detects steering torque applied to a shaft through a steering shaft by a steering operation of a driver. In the electric power steering apparatus, a motor is driven to provide assist force (to apply assist steering force) for a steering operation of a driver in response to a detection signal from the torque sensor, so that steering force required by a driver is reduced and a comfortable steering feeling is provided for the driver.

[0006] As an example of a torque sensor mounted in such an electric power steering apparatus, there has been known a magnetostrictive torque sensor, which is disclosed, for example, in Japanese Laid-open Patent Application No. 2004-239652 (paragraph [0024~0034], FIGS. 1, 7~9).

[0007] In the magnetostrictive torque sensor, a magnetostrictive film (for example, a Ni—Fe alloy film) having magnetic anisotropy is attached on the surface of a shaft. When torque is applied to the shaft from outside, the magnetostrictive torque sensor magnetically detects changes of a magnetic characteristic (magnetic permeability) of the magnetostrictive film, which is generated in accordance with a twisting of the shaft, without contacting the magnetostrictive film.

[0008] A description will be given on the conventional magnetostrictive torque sensor by taking as an example a magnetostrictive torque sensor mounted in an electric power steering apparatus of a vehicle.

[0009] FIG. **9** schematically illustrates the conventional electric power steering apparatus including the torque sensor.

[0010] As shown in FIG. **9**, an electric power steering apparatus **101** mainly includes a torque sensor **103** that detects steering torque applied from a steering wheel **102**, a motor **104** that applies assist steering force for an operation of the steering wheel **102**, a reduction gear **105** that increases rotational torque generated by the motor **104**, an electrical control unit (ECU) **107** that drives the motor **104** in response to a detection signal from the torque sensor **103** or a vehicle speed sensor **106**, a rack shaft **109** and a pinion gear **110** that transmit rotation of the motor **104** to wheels **108**, **108**, and change a direction of the wheels **108**, **108**. The reduction gear **105** includes a worm **105**A and a worm wheel **105**B.

[0011] In the electric power steering apparatus **101** configured as above, steering torque applied by a steering operation of a driver is detected by the torque sensor **103**, and the motor **104** is driven by the ECU **107** in response to a detection signal (torque signal) from the torque sensor **103**, a detection signal (vehicle speed signal) from the vehicle speed sensor **106**, or the like. Rotational torque generated by the motor **104** is increased by the reduction gear **105**, and then is transmitted to the wheels **108**, **108** through the pinion gear **110** and the rack shaft **109**.

[0012] In the electric power steering apparatus **101**, assuming that steering torque applied by a steering operation is TH, rotational torque transmitted to the pinion gear **110** is TP, and a constant that associates with an amount of assist torque generated by the motor **104** is KA, thereby obtaining the equation TH=TP/(1+KA). Therefore, it is possible to reduce steering force required by a driver by using the assist torque generated by the motor **104**.

[0013] Next, a description will be given on the torque sensor **103** with reference to FIG. **10**.

[0014] FIG. **10** is a sectional view of a main part of a conventional electric power steering apparatus where a magnetostrictive torque sensor is mounted.

[0015] As shown in FIG. **10**, the torque sensor **103** is contained in a sensor housing **111** that includes an upper housing **111**A and a lower housing **111**B. The torque sensor **103** mainly includes a shaft **114** that is connected to a steering shaft **102**A (see FIG. **9**) of the steering wheel **102** (see FIG. **9**) and is rotatably supported in the sensor housing **111** via a shaft bearing **112** or the like, coil units **121**, **122** having coils (detection units) **115**, **116** that are disposed separately in the axial direction on the inner periphery side of the upper housing **111**A, and magnetostrictive films **117**, **118** that are formed on the outer periphery side (outer surface) of the shaft **114** so as to face the coils **115**, **116** and that have magnetic anisotropy in opposite directions to each other.

[0016] When steering torque is applied to the shaft **114** from the steering wheel **102** (see FIG. **9**), each of the coils **115**, **116** electrically detects changes of a magnetic characteristic of the magnetostrictive films **117**, **118** in accordance with a twisting of the shaft **114**, and based on the detection result, a direction and an amount of steering torque applied to the shaft **114** are detected.

[0017] The upper housing **111**A is made of a light alloy, such as an aluminum alloy or a magnesium alloy. Yokes **119**, **120** of the coil units **121**, **122** are made of a magnetic steel sheet or the like, which has a high magnetic characteristic and a soft magnetic property. The shaft (steering shaft) **114** is made of an iron alloy such as a SC or SCM material, and on the outer periphery side of the shaft **114** are formed the magnetostrictive films **117**, **118** of Fe—Ni or Fe—Cr by plating, vapor deposition, or the like.

[0018] In the torque sensor **103** disclosed in the above publication, however, the upper housing **111**A of the sensor housing **111**, the yokes **119**, **120**, and the shaft **114**, which are shown in FIG. **10**, are made of different metallic materials, thereby having a different coefficient of linear expansion.

[0019] Compared to an iron alloy of the magnetostrictive films **117**, **118** and the shaft **114** and a magnetic steel sheet of the yokes **119**, **120**, an aluminum alloy of the sensor housing **111** has approximately twice the coefficient of linear expansion as an iron alloy and a magnetic steel sheet.

[0020] The electric power steering apparatus **101** of a vehicle is used in an environment at a temperature of −40° C. to 80° C., and can be used at a more severe temperature.

[0021] At a high temperature, a gap grows between the sensor housing **111** and the yokes **119**, **120** due to an expansion of the sensor housing **111** relative to the yokes **119**, **120**.

[0022] In the torque sensor **103**, the amount of pressure between the yokes **119**, **120** and the sensor housing **111** decreases due to the gap, thereby causing backlash between the yokes **119**, **120** and the sensor housing **111**. As a result, in the torque sensor **103**, a gap "a" between the yokes **119**, **120** and the magnetostrictive films **117**, **118** changes, and the change of the gap "a" varies a magnetic path, thereby changing an output from the torque sensor **103**. For this reason, detection accuracy of the torque sensor **103** is deteriorated. Further, an output from the torque sensor **103** varies because the shaft **114** is offset in the axial direction, that is, the coils **115**, **116** slides relative to the position of the magnetostrictive films **117**, **118** in the axial direction. For this reason, in the torque sensor **103**, a holding portion of the coil units **115**, **116** must be processed with high dimensional accuracy.

[0023] In order to reduce the backlash between the yokes **119**, **120** and the sensor housing **111**, the torque sensor **103** will have increase in the number of components and man-hours for assembling, and the complexity of the configuration.

SUMMARY OF THE INVENTION

[0024] Therefore, an object of the present invention is to provide a torque sensor having a high productivity and an easy configuration and a method of manufacturing the torque sensor.

[0025] According to the first aspect of the present invention, there is provided a torque sensor comprising: a magnetic characteristic change portion formed on a rotary shaft; and a plurality of coil units having a substantially cylindrical shape, the plurality of coil units including first and second coil units, each including a detection coil arranged to face the magnetic characteristic change portion, the first and the second coil units arranged in an axial direction of the shaft. In the torque sensor, the first coil unit and the second coil unit are fixed in an integrally molded resin.

[0026] In the torque sensor according to the first aspect of the present invention, the first coil unit and the second coil unit are fixed in an integrally molded resin (insert molding) so that the molded resin member, the first coil unit, and the second coil unit can be maintained at a certain distance from each other, thereby making it possible to stabilize an output of the torque sensor and the detection accuracy thereof.

[0027] Because the first coil unit and the second coil unit are fixed in an integrally molded resin, there is no need to control processing accuracy in order to improve dimensional accuracy between the respective members, thereby improving productivity of the torque sensor.

[0028] Because the molded resin shrinks after molding, the coil units disposed inside the molded resin member are maintained with pressure in the axial and diametrical direction. For this reason, there is no need to provide a spring member to prevent backlash between the members due to changes of a temperature. As a result, it is possible to improve detection accuracy, reduce the number of components and man-hours for assembling, simplify the configuration, and improve mass productivity.

[0029] According to the second aspect of the present invention, there is provided the torque sensor further comprising a spacer interposed between the first coil unit and the second coil unit.

[0030] In the torque sensor according to the second aspect of the present invention, the first coil unit, the second coil unit, and the spacer, which is interposed between the first and second coil units, are fixed in an integrally molded resin so that the molded resin member, the first and second coil units, and the spacer are maintained at a certain distance from each other, thereby making it possible to stabilize an output of the torque sensor and the detection accuracy thereof.

[0031] Because the first coil unit, the second coil unit, and the spacer are fixed in an integrally molded resin, there is no need to control processing accuracy in order to improve dimensional accuracy between the respective members, thereby improving productivity of the torque sensor.

[0032] According to the third aspect of the present invention, there is provided the torque sensor wherein the first coil unit, the second coil unit, and the spacer are fixed in a housing integrally molded with resin.

[0033] In the torque sensor according to the third aspect of the present invention, the first coil unit, the second coil unit, and the spacer are maintained in one housing, thereby making it possible to reduce the number of components and man-hours for assembling.

[0034] According to the fourth aspect of the present invention, there is provided the torque sensor wherein the spacer includes a bearing having a smaller inner diameter than inner diameters of the first coil unit and the second coil unit.

[0035] In the torque sensor according to the fourth aspect of the present invention, because the spacer includes a bearing having a smaller inner diameter than those of the first coil unit and the second coil unit, a certain distance can be maintained between the shaft and the first and second coil units, thereby improving detection accuracy of the torque sensor.

[0036] According to the fifth aspect of the present invention, the torque sensor is employed in an electric power steering apparatus that steers a vehicle by driving a motor in accordance with steering torque.

[0037] In the torque sensor according to the fifth aspect of the present invention, the torque sensor is employed in an electric power steering apparatus as a sensor dedicated for detection of steering torque, and therefore the torque sensor is not affected by backlash between the members due to heat expansion even in a severe environment at a high temperature, thereby obtaining the electric power steering apparatus capable of giving a comfortable steering feeling.

[0038] According to the sixth aspect of the present invention, there is provided the torque sensor further comprising a yoke disposed on an outer circumference of each of the plurality of detection coils.

[0039] In the torque sensor according to the sixth aspect of the present invention, the yoke is disposed on the outer circumference of each of the plurality of detection coils, so that magnetic permeability can be improved and detection accuracy of the torque sensor can be increased.

[0040] According to the seventh aspect of the present invention, there is provided the torque sensor further comprising a spacer disposed under the second coil unit in the axial direction of the shaft.

[0041] In the torque sensor according to the seventh aspect of the present invention, a spacer is disposed under the second coil unit in the axial direction of the shaft, thereby making it

possible to maintain a certain distance between respective members. Therefore, it is possible to stabilize an output of the torque sensor and the detection accuracy thereof.

[0042] Because the first coil unit, the second coil unit, and the spacer are fixed in an integrally molded resin, there is no need to control processing accuracy in order to improve dimensional accuracy between the respective members, thereby improving productivity of the torque sensor.

[0043] According to the eighth aspect of the present invention, there is provided the torque sensor wherein a yoke disposed in the second coil unit has a tapered surface at a lower end thereof, and the spacer is a ring-shaped member having a tilted surface to contact with the tapered surface.

[0044] In the torque sensor according to the eighth aspect of the present invention, a tapered surface is formed on a lower end of a yoke disposed in the second coil unit, and the spacer is a ring-shaped member having a tilted surface to contact with the tapered surface. Therefore, the tilted surface of the spacer and the tapered surface of the yoke contact with each other, thereby maintaining the respective members in the axial direction of the shaft. Therefore, it is possible to stabilize an output of the torque sensor and the detection accuracy thereof

[0045] According to the ninth aspect of the present invention, there is provided a method of manufacturing a torque sensor comprising a magnetic characteristic change portion formed on a rotary shaft, a plurality of coil units having a substantially cylindrical shape, the plurality of coil units including first and second coil units, each including a detection coil arranged to face the magnetic characteristic change portion, the method using a centering rod and a die set including a base die and other dies. The method comprises the steps of: fitting internal members including the first coil unit, the second coil unit, and a spacer on the centering rod so as to dispose the internal members on the base die; setting the other dies on the base die; and molding a resin, in which the first coil unit, the second coil unit, and the spacer are fixed.

[0046] In the torque sensor according to the ninth aspect of the present invention, the first coil unit, the second coil unit, and the spacer are fixed in an integrally molded resin in the molding process so that the respective members can be integrally maintained and contained at once. Therefore, it is possible to reduce dimension errors between the components of the torque sensor, improve detection accuracy, and reduce the number of the components and man-hours for assembly.

[0047] According to the tenth aspect of the present invention, there is provided the method of manufacturing the torque sensor, wherein a yoke is disposed on an outer circumference of each of the plurality of detection coils.

[0048] In the method of manufacturing a torque sensor according to the tenth aspect of the present invention, magnetic permeability can be improved and detection accuracy of the torque sensor can be increased.

[0049] In the torque sensor and the method of manufacturing the torque sensor according to the present invention, it is possible to reduce the number of the components and man-hours for assembly, simplify the configuration of the torque sensor, and improve productivity.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] The object and features of the present invention will become more readily apparent from the following detailed description taken in conjunction with the accompanying drawings in which:

[0051] FIG. **1** illustrates an electric power steering apparatus including a torque sensor according to an embodiment of the present invention;

[0052] FIG. **2** is a schematic sectional view of a main part of an electric power steering apparatus where a torque sensor according to an embodiment of the present invention is disposed;

[0053] FIG. **3** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a process of disposing internal members;

[0054] FIG. **4** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a process of setting a die;

[0055] FIG. **5** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a molding process;

[0056] FIG. **6** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains the molded-in upper housing **21**;

[0057] FIG. **7** illustrates a modified example of a torque sensor and a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains the torque sensor in a molding process;

[0058] FIG. **8** illustrates the second modified example of a torque sensor and a method of manufacturing a torque sensor according to an embodiment of the present invention, and is a schematic sectional view of a main part of an electric power steering apparatus where a torque sensor is mounted;

[0059] FIG. **9** schematically illustrates a conventional electric power steering apparatus; and

[0060] FIG. **10** is a sectional view of a main part of a conventional electric power steering apparatus wherein a magnetostrictive torque sensor is mounted.

DETAILED DESCRIPTION OF THE INVENTION

[0061] A description will be given on an example of a torque sensor **1** and a method of manufacturing the torque sensor **1** according to an embodiment of the present invention with reference to FIGS. **1** to **3**.

[0062] The torque sensor **1** according to an embodiment of the present invention detects rotational torque of a shaft **4**, which is caused by rotational force acting on the shaft **4**. As an example of a torque sensor according to an embodiment of the present invention, a description will be given on a torque sensor **1** mounted on an electric power steering apparatus **11** to detect steering torque.

[0063] Prior to a description of the torque sensor **1** and a method of manufacturing the torque sensor **1**, a description will be given on an electric power steering apparatus **11** of a vehicle, on which the torque sensor **1** is mounted.

[0064] A direction relative to the torque sensor **1** changes from right to left or up and down depending on the direction, in which the torque sensor **1** is placed, and therefore in the description the upper side of the drawings is defined to be the upward direction.

[0065] FIG. **1** schematically illustrates an electric power steering apparatus including a torque sensor according to an embodiment of the present invention.

<<Configuration of the Electric Power Steering Apparatus>>

[0066] As shown in FIG. **1**, the electric power steering apparatus **11** has the almost same configuration as that of the

electric power steering apparatus **101** including the torque sensor **103**, which is above mentioned with reference to FIGS. **9** and **10**, except for a configuration of the torque sensor **1**.

[0067] Specifically, the electric power steering apparatus **11** shown in FIG. **1** mainly includes the torque sensor **1** that detects steering torque applied from a steering wheel **12** by a driver, a motor **14** that applies assist steering force to a driver's steering, a reduction gear **15** that increases rotational torque generated by the motor **14**, an electrical control unit (ECU) **17** that controls the motor **14** in response to a detection signal from the torque sensor **1** or a vehicle speed sensor **16**, a rack shaft **19** and a pinion gear **41** that transmit rotation of the motor **14** to wheels **18**, **18** and change a direction of the wheels **18**, **18**.

<<Configuration of the Torque Sensor>>

[0068] FIG. **2** is a schematic sectional view of a main part of the electric power steering apparatus **11** where the torque sensor **1** according to an embodiment of the present invention is mounted.

[0069] As shown in FIG. **2**, the torque sensor **1** includes a plurality of coil units **7** having an substantially cylindrical shape, the coil units **7** including a plurality of coils (detection coil) **71**, **72** arranged to face a magnetic characteristic change portion **5** (magnetostrictive films **51**, **52**) formed on the rotary shaft **4**, and yokes **73**, **74** disposed on the outer circumference of the coils **71**, **72**.

[0070] Hereinafter, an embodiment of the present invention will be described with the torque sensor **1** including the magnetostrictive films **51**, **52** and the coil units **7** (a first coil unit **7**A and a second coil unit **7**B).

[0071] When steering torque is applied to the shaft **4** from the steering wheel **12** (see FIG. **1**), the torque sensor **1** electrically detects changes of a magnetic characteristic of the magnetostrictive films **51**, **52**, which are generated in accordance with a twisting of the shaft **4**, by using the coils **71**, **72** or the like, thereby detecting a direction and an amount of the steering torque applied to the shaft **4**.

[0072] The torque sensor **1** includes the first coil unit **7**A and the second coil unit **7**B, and the first coil unit **7**A and the second coil unit **7**B are disposed in the axial direction of the shaft **4** together with spacers **6**, **36**. The first coil unit **7**A, the second coil unit **7**B, and the spacers **6**, **36**, which maintain a certain distance between the respective members, are fixed and housed integrally in a sensor housing **2** that is molded with resin.

<Configuration of the Shaft>

[0073] As shown in FIG. **1**, the shaft **4** is a steering shaft that is coupled to the steering wheel **12** via universal joints **13**, **13** and turns together with the steering wheel **12**. As shown in FIG. **2**, the shaft **4** is integrally formed with the pinion gear **41** on a lower end portion thereof, and is rotatably accommodated in the sensor housing **2** via a shaft bearing **3** in the vertical direction. The magnetostrictive films **51**, **52** of the magnetic characteristic change portion **5** are formed on two parts of the outer circumference side of the shaft **4** so as to face the coils **71**, **72**. An upper end portion of the shaft **4** protrudes from the sensor housing **2** through a shaft opening **21***a* of an upper housing **21** and a ring-shaped sealing member **10**.

[0074] The shaft **4** is made of, for example, chrome molybdenum steel such as SCM822. The chrome molybdenum steel of the shaft **4** is subjected to heat treatment such as quenching in advance, and then the magnetostrictive films **51**, **52** are attached on the shaft **4** by a physical vapor deposition (PVD) method such as spattering or ion plating, a plating method, a plasma spraying method or the like. The hardness of the shaft **4** is set to be in the range of HRC 40-65 of Rockwell hardness.

<Configuration of the Magnetic Characteristic Change Portion>

[0075] On the magnetic characteristic change portion **5**, a magnetic characteristic (magnetic permeability) of the magnetostrictive films **51**, **52** changes according to distortion of the shaft **4**, the distortion generated when steering torque is applied to the shaft **4**. The magnetic characteristic change portion **5** includes the magnetostrictive films **51**, **52** that are vertically arranged with a predetermined space interposed therebetween on the outer circumference side (outward surface) of the shaft **4** in the axial direction.

[0076] For example, a magnetrostrictive member made of a Fe—Ni or Fe—Cr alloy film or the like is integrally fixed on the shaft **4** by plating or vapor deposition so as to form the magnetostrictive films **51**, **52**. The magnetostrictive films **51**, **52** include magnetrostrictive members that have magnetic anisotropy in opposite directions to each other.

<Configuration of the Coil Unit>

[0077] The coil unit **7** electrically detects changes of a magnetic characteristic of the magnetostrictive films **51**, **52**, thereby detecting steering torque applied to the shaft **4**. The coil unit **7** includes the first coil unit **7**A and the second coil unit **7**B. The first coil unit **7**A, the second coil unit **7**B, and the spacer **36**, which maintains a certain distance between the first coil unit **7**A and the second coil unit **7**B, are fixed in the upper housing **21** that is molded with resin.

<Configuration of the First Coil Unit and the Second Coil Unit>

[0078] The first coil unit **7**A and the second coil unit **7**B include the coils **71**, **72** and the yokes **73**, **74**, which are disposed in the periphery of the coils **71**, **72** to hold the coils **71**, **72**, respectively. The first coil unit **7**A and the second coil unit **7**B are arranged to face the magnetic characteristic change portion **5** with a predetermined distance interposed therebetween. The first coil unit **7**A and the second coil unit **7**B are detection units to detect steering torque applied to the shaft **4** by detecting changes of a magnetic characteristic of the magnetic characteristic change portion **5**.

[0079] As shown in FIG. **1**, the first coil unit **7**A and the second coil unit **7**B are electrically connected to the ECU **17** via detection circuits **75**, **76**, which detect a torque detection voltage outputted from the coils **71**, **72** in accordance with changes of a magnetic characteristic when electricity is alternately applied to the coils **71**, **72**.

<Configuration of the Coil>

[0080] The coils **71**, **72** are composed of magnetizing coil dedicated for detection. As shown in FIG. **2**, the coils **71**, **72** are electrically conducted to the magnetostrictive films **51**, **52** and detect changes of a magnetic characteristic (magnetic permeability) of the magnetostrictive film **51**, **52** when steering torque is applied to the shaft **4**. The coils **71**, **72** are separately disposed in the axial direction on the inner circumference side of the upper housing **21**. The coils **71**, **72** wound

around bobbins (not shown) are disposed inside the yokes **73**, **74**, respectively, and arranged to face the magnetostrictive films **51**, **52** with a predetermined space b interposed therebetween.

<Configuration of the Yoke>

[0081] As shown in FIG. **2**, the yokes **73**, **74** form outer frames of the coils **71**, **72**, and are, for example, ring-shaped members having an substantially transverse U-shape in a sectional view. The yokes **73**, **74** are made of a steel sheet or the like that has a soft magnetic property. On the outer circumference end of the top and bottom sides of the yokes **73**, **74** are respectively provided tapered surfaces **73***a*, **74***a*, which are cut off at approximately 45°. The spacer **36**, which includes a bearing **34** (shaft bearing **3**) held by a ring-shaped holing member **35**, is interposed between the yokes **73**, **74** in the axial direction of the shaft **4** so that the spacer **36** maintains a certain distance between the yokes **73**, **74**.

[0082] The upper yoke **73**, the ring-shaped holding member **35**, the lower yoke **74**, the spacer **6**, and the bearing **33** are disposed in series in the sensor accommodating portion **21***b*, which is molded with resin, through the opening portion **21***c* in the axial direction, The tapered surface **74***a* provided on the lower end of the lower yoke **74** contacts with a tilted surface **6***a* of the spacer **6**. Thereby, the yokes **73**, **74** are contained in the sensor housing **2**.

[0083] An angle of the tapered surface **73***a*, **74***a*, and the tilted surface **6***a* of the spacer **6**, which will be described later in detail, is not limited to 45°, but may be changed to 30° or 60° if required.

<Configuration of the Shaft Bearing (Spacer)>

[0084] As shown in FIG. **2**, the shaft bearing **3** is a member for rotatably supporting the shaft **4**, and, for example, includes a plurality of bearings **31**, **32**, **33**, and **34**. The bearings **31**, **32** include a ball bearing or a roller bearing, and are attached in the lower housing **22** so as to support the lower end portion of the shaft **4** and the shaft **4** on the upper side of the pinion gear **41**.

[0085] The bearings **33**, **34** include, for example, a ball bearing. The bearings **33**, **34** are attached on the shaft **4** and are disposed inside the sensor accommodating portion **21***b* of the upper housing **21**. The bearing **34** and the ring-shaped holding member **35** form the spacer **36** that maintains a certain distance between the first coil unit **7**A and the second coil unit **7**B, and also function as a shaft bearing of the shaft **4**. Similarly to the spacer **36**, the bearing **33** and the spacer **6**, which will be described later, have a function to maintain a certain distance between the members.

[0086] The bearing **33**, which is attached on the lower end portion of the sensor accommodating portion **21***b*, contacts with the bottom surface of the spacer **6**. The inner circumference of the bearing **33** is attached on the shaft **4** and the outer circumference thereof is fixed in the upper housing **21** that is molded with resin.

[0087] The bearing **34**, which is arranged in a middle portion of the sensor accommodating portion **21***b*, is attached inside the ring-shaped holding member **35**, and is made smaller than the bearing **33** disposed in the lower end portion of the sensor accommodating portion **21***b*. The inner circumference of the bearing **34** is attached on the shaft **4** and the outer circumference thereof is fixed on the ring-shaped holding member **35**. An inner diameter of the inner circumference of the bearing **34** is made smaller than those of the first coil unit **7**A and the second coil unit **7**B so that the bearing **34** maintains a certain space b between the coil unit **7** and the magnetic characteristic change portion **5**.

[0088] The top surface of the ring-shaped holding member **35** contacts with the bottom surface of the upper yoke **73** and the bottom surface of the holding member **35** contacts with the top surface of the lower yoke **74** so that the holding member **35** is fixed in the upper housing **21** that is molded with resin.

<Configuration of the Spacer>

[0089] As shown in FIG. **2**, the spacer **6** and the bearing **33** have a function to keep the second coil unit **7**B at a certain height. The spacer **6** is a ring-shaped member made of metal, and on the outer circumference portion thereof, is provided with a tilted surface **6***a* that tilts towards the axis of the shaft **4** and has an substantially rectangular triangle shape in a sectional view. The spacer **6** is interposed between the lower yoke **74** and the bearing **33**, and the tilted surface **6***a* formed on the outer circumference portion contacts with the tapered surface **74***a* of the lower yoke **74** all the time. Thereby, the spacer **6** is disposed in the sensor accommodating portion **21***b*.

[0090] The spacer **6** is contained in the sensor accommodating portion **21***b* with the tilted surface **6***a* of the spacer **6** in contact with the tapered surface **74***a* of the yoke **74**, so that the yokes **73**, **74**, the ring-shaped holding member **35**, and the bearing **33**, which are arranged in the sensor accommodating portion **21***b*, are pressed in the axial direction and therefore the adjacent members are pressed to each other.

<Configuration of the Sensor Housing>

[0091] The sensor housing **2** houses the torque sensor **1** or the like, and includes the upper housing **21**, which is disposed on the upper side of the sensor housing **2**, and the lower housing **22**, which is fitted onto the lower side of the upper housing **21** and is tightened by bolting. In the sensor housing **2**, at least the upper housing **21** is made of resin.

[0092] It should be noted that the upper housing **21**, which forms the sensor housing **2**, corresponds to "a housing" set forth in the appended claims.

[0093] The upper housing **21** is a housing that is molded with resin (so-called insert molding) and integrally formed with the first coil unit **7**A, the second coil unit **7**B, the bearings **33**, **34**, the ring-shaped holding member **35**, and the spacer **6**. The upper housing **21** includes the sensor accommodating portion **21***b*, the shaft opening **21***a*, through which the shaft **4** is inserted, and an opening portion **21***c*. The first coil unit **7**A, the second coil unit **7**B, the bearings **33**, **34**, the ring-shaped holding member **35**, and the spacer **6** are fixed in the sensor accommodating portion **21***b*, and the adjacent members softly contact with one another. In the upper housing **21**, the shaft opening **21***a* is provided with the sealing member **10** so that air tightness can be provided inside the sensor housing **2**.

[0094] A material of the upper housing **21** includes, for example, a synthetic resin such as MC nylon (registered trademark), which is superior in mechanical strength, heat resistance, friction resistance, chemical resistance, and machining property.

[0095] The lower housing **22** houses the shaft bearing **3**, the pinion gear **41**, or the like. Other members such as the motor **14** (see FIG. **1**), the reduction gear **15** (see FIG. **1**), or the rack

shaft **19** are contained in the lower housing **22**. The lower housing **22** is made of resin for example, but may be made of metal.

<<Method of Manufacturing the Torque Sensor>>

[0096] With reference to FIGS. **3** to **6**, a description will be given on a method of manufacturing the torque sensor **1** according to an embodiment of the present invention. The torque sensor **1** is manufactured by performing the molding with a synthetic resin such as MC nylon (registered trademark) in the manner as follows.

<Explanation of a Process of Disposing Internal Members>

[0097] FIG. **3** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a process of disposing internal members.

[0098] With reference to FIG. **3**, a description will be given on a die **8** that is used in the process of disposing internal members. The internal members means members to be disposed inside the upper housing **21** (see FIG. **2**) when molding the upper housing **21** in resin.

[0099] As shown in FIG. **3**, a base die **81**, which constitutes the die **8** for forming the torque sensor **1**, is a die to form the lower side portion of the upper housing **21** (see FIG. **2**), and includes a base **82** and an upper centering rod **83**.

[0100] The base **82** has a lower centering rod **82***a* and a blind hole **82***b*. The bearing **33**, the spacer **6**, and the second coil unit **7**B are fitted onto the lower centering rod **82***a*, which has a cylindrical shape, so that the lower centering rod **82***a* is supported by the members. The blind hole **82***b* is formed in the center of the upper end surface of the lower centering rod **82***a*, and is inserted with a protrusion **83***a* formed in the center of the lower end portion of the upper centering rod **83**. The base **82** and the lower centering rod **82***a* are formed with high dimensional accuracy. The first coil unit **7**A and the second coil unit **7**B are held on the base die **81** with high accuracy by the lower centering rod **82***a*.

[0101] The bearing **34** attached inside the ring-shaped holding member **35** and the first coil unit **7**A are fitted onto the upper centering rod **83** so that the upper centering rod **83** is supported by the members. The upper centering rod **83** is integrally formed with the protrusion **83***a*, which is designed to connect the centering rod **83** with the base **82**, in the center of the lower end portion of the centering rod **83**. An inner diameter of the upper centering rod **83** is made smaller than those of the first coil unit **7**A and the second coil unit **7**B, so that it is possible to pull out the upper centering rod **83** after molding. Therefore, the upper centering rod **83** and the stand **82** are formed separately.

[0102] It should be noted that the lower centering rod **82***a* and the upper centering rod **83** correspond to "a centering rod" set forth in the appended claims.

[0103] In the first process of disposing the internal members, the bearing **33**, the spacer **6**, the second coil unit **7**B, the bearing **34** attached inside the ring-shaped holding member **35**, and the first coil unit **7**A, which are disposed inside the sensor housing **2**, are fitted onto the lower centering rod **82***a* and the upper centering rod **83** (a centering rod) in series, so that the internal members are disposed on the base **82** of the base die **81**.

<Explanation of a Process of Setting a Die>

[0104] FIG. **4** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a process of setting a die.

[0105] With reference to FIG. **4**, a description will be given on the die **8** that is used in the die setting process.

[0106] As shown in FIG. **4**, the die **8**, which is arranged above the base die **81**, includes a side portion die **84**, a side portion die **85**, and an upper portion die **86**. The side portion die **84** is designed to form a side portion of the upper housing **21** (see FIG. **2**). The side portion die **85** is designed to form a side portion of the upper housing **21** (see FIG. **2**) and form openings **85***a* so as to provide interfaces in the upper housing **21**. The upper portion die **86** is designed to form an upper portion of the upper housing **21**.

[0107] In the second process of setting the die, the side portion dies **84**, **85** and the upper portion die **86** are set on the base die **81**. After setting the dies, the base die **81**, the side portion dies **84**, **85** and the upper portion die **86** are clamped together.

[0108] It should be noted that the side portion dies **84**, **85** and the upper portion die **86** correspond to "other dies" set forth in the appended claims.

<Explanation of a Molding Process>

[0109] FIG. **5** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains a molding process.

[0110] As shown in FIG. **5**, an injection nozzle (not shown) injects a molten resin P through a port (not shown) so that the die **8** is filled with the molten resin P, thereby forming a housing including the first coil unit **7**A, the second coil unit **7**B, the spacer **6**, or the like by resin molding.

[0111] FIG. **6** illustrates a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains the molded-in upper housing **21**.

[0112] After the die **8** is cooled off, the upper portion die **86**, the side portion dies **84**, **85**, the upper centering rod **83**, and the base die **81** are removed to take out a product S. Then, the product S (upper housing **21**) as shown in FIG. **6** is obtained.

[0113] According to the method of manufacturing the torque sensor **1**, as shown in FIG. **5**, the first coil unit **7**A and the second coil unit **7**B are supported with high accuracy by the lower centering rod **82***a* of the base die **81** and the upper centering rod **83**, which are regarded as the shaft **4** (see FIG. **2**), so as to form the product S (see FIG. **6**). Furthermore, the product S (see FIG. **6**) are formed with high accuracy relative to the base **82** of the base die **81**, which are regarded as the upper housing **21**.

[0114] As shown in FIG. **6**, the above molded-in product S (torque sensor **1**) is one component where the first coil unit **7**A, the ring-shaped holding member **35**, the second coil unit **7**B, the spacer **6**, the bearing **33**, and the upper housing **21** are integrally fixed. Therefore, it is possible to reduce the number of components and man-hours for assembling, and to eliminate the control of dimensional accuracy of each of the members disposed inside the upper housing **21** in case of changes of a temperature.

[0115] As shown in FIG. **2**, the upper housing **21** is fitted on the lower housing **22**, on which the shaft **4** having the magnetostrictive films **51**, **52** is mounted, and the housings **21**, **22** are tightened by bolting, thereby obtaining the torque sensor **1**.

[0116] Compared to a conventional torque sensor, in which an upper housing and a coil unit are separately formed, the torque sensor **1** configured as above need not control processing accuracy to improve dimensional accuracy, or need not be provided with a spring member to prevent backlash between

the members, which is generated due to changes of a temperature. Therefore, it is possible to reduce the number of components, simplify the configuration and improve mass productivity.

<<Function of Torque Sensor>>

[0117] With reference to FIGS. **1** and **2**, a description will be given on a function of the torque sensor **1**.

[0118] In the electric power steering apparatus **11** as shown in FIG. **1**, steering torque applied by a driver's steering operation is detected by the torque sensor **1**, and the motor **14** is driven by the ECU **17** in response to a detection signal from the torque sensor **1**, the vehicle speed sensor **16**, or the like. The torque generated by the motor **14** is increased by the reduction gear **15**, and then is transmitted to the wheels **18**, **18** through the pinion gear **41** and the rack shaft **19**.

[0119] As shown in FIG. **2**, the tilted surface **6***a* of the spacer **6** and the tapered surface **74***a* of the second coil unit **7**B contact with each other so that the torque sensor **1** is disposed inside the upper housing **21**. In the molded-in torque sensor **1**, the resin of which the upper housing **21** is formed shrinks after molding. Therefore, the first coil unit **7**A, the ring-shaped holding member **35**, the second coil unit **7**B, the spacer **6**, the bearing **33**, and the upper housing **21**, which are disposed inside the upper housing **21**, are held together with pressure in the axial and diametrical direction. For this reason, it is possible to prevent backlash between each of the members disposed in the upper housing **21** due to changes of a temperature.

[0120] As a result, in the torque sensor **1**, the members have a certain distance with each other and have no backlash between the members, thereby maintaining high accuracy for detecting steering torque.

[0121] Because the torque sensor **1** is employed in the electric power steering apparatus **11** that applies assist steering force to a steering system of a vehicle, detection accuracy of steering torque can be improved by the torque sensor **1**, and the electric power steering apparatus **11** can be provided with high performance, high reliability or the like.

MODIFIED EXAMPLE

[0122] It should be noted that the present invention is not limited to the above-mentioned embodiment, but various modifications or changes can be made within the scope of the technical idea of the invention. The present invention should include such modifications or changes.

[0123] With reference to FIGS. **7** and **8**, a description will be given on modified examples of the present invention. In the modified examples, a description will be omitted for members that have the same function as that of the torque sensor **1** according to the above-mentioned embodiment shown in FIGS. **1** to **6**.

First Modified Example

[0124] With reference to FIG. **7**, the first modified example of the present invention will be described.

[0125] FIG. **7** illustrates the first modified example of a torque sensor and a method of manufacturing a torque sensor according to an embodiment of the present invention, and explains the torque sensor in a molding process.

[0126] The torque sensor **1** (see FIG. **2**) of the above-described embodiment may have such a configuration that a spacer **6**A including a relatively small-sized bearing **37** is interposed between a first coil unit **7**C and a second coil unit **7**D, as shown in a torque sensor **1**A of the first modified example of FIG. **7**.

[0127] As shown in FIG. **7**, the torque sensor **1**A may not include the spacer **6** or the bearing **33** (see FIG. **2**) that are mentioned in the above-mentioned embodiment. It is, therefore, possible to downsize and simplify the torque sensor **1**A.

[0128] Furthermore, the lower centering rod **82***a* and the upper centering rod **83** of the die **8**, which are employed in the method of manufacturing the torque sensor **1** in the above embodiment as shown in FIG. **3**, may have a configuration of a base die **81**A of a die **8**A in the modified example of FIG. **7**. That is, a centering rod **83**A may be integrally formed with the base die **81**A.

[0129] With such a configuration, it is possible to further improve dimensional accuracy of the centering rod **83**A because the centering rod **83**A has no connections.

Second Modified Examples

[0130] FIG. **8** illustrates the second modified example of a torque sensor and a method of manufacturing a torque sensor according to an embodiment of the present invention, and is a schematic sectional view of a main part of an electric power steering apparatus where a torque sensor is mounted.

[0131] In FIG. **2**, the first coil unit **7**A and the second coil unit **7**B include the coils **71**, **72** and the yokes **73**, **74**. However, as shown in FIG. **8**, the yokes **73**, **74** may be removed as long as the coils **71**, **72** are disposed.

[0132] With such a configuration, it is possible to reduce the number of the components by removing the yokes **73**, **74**, omit a part of the internal member disposing process (the first process) upon manufacturing the torque sensor, and simplify a configuration of the torque sensor. Although magnetic permeability decreases due to the removal of the yokes **73**, **74**, the first and second coil units can be used as a torque sensor.

[0133] In this case, the spacer **36** is interposed between the coil **71** and the coil **72**, and the spacer **6** is interposed between the coil **72** and the bearing **33**.

Other Modified Example

[0134] For example, each of the first coil unit **7**A and the second coil unit **7**B, which are shown in FIG. **2**, may have an substantially E shape in a sectional view, and have a two layer structure where the two coils **71** and the two coils **72** are formed in the first coil unit **7**A and the second coil unit **7**B, respectively.

[0135] The spacer **6** shown in FIG. **2** may be an elastic member such as a plate spring, a disc spring, a spring washer, or a coil spring in order to bias the coil unit **7** contained in the sensor accommodating portion **21***b*, and prevent backlash between the members, space between the first coil unit **7**A and the second coil unit **7**B, or the like.

[0136] The above description has been given on the torque sensor **1** that is used in the electric power steering apparatus **11**, which steers a vehicle by driving the motor **14** in accordance with steering torque, but the torque sensor **1** may be used for a torsion bar or other various apparatus.

What is claimed is:

1. A method of manufacturing a torque sensor comprising a magnetic characteristic change portion formed on a rotary shaft, a plurality of coil units having a substantially cylindrical shape, the plurality of coil units including first and second coil units, each including a detection coil arranged to face the

magnetic characteristic change portion, the method using a centering rod and a die set including a base die and other dies, the method comprising the steps of:

fitting internal members including the first coil unit and the second coil unit on the centering rod so as to dispose the internal members on the base die;

setting the other dies on the base die; and

molding a resin, in which the first coil unit and the second coil unit are fixed.

2. The method of manufacturing the torque sensor according to claim **1**,

wherein a yoke is disposed on an outer circumference of each of the plurality of detection coils.

3. The method according to claim **1**, further comprising the steps of:

removing the base die, the other dies and the centering rod after molding the resin to obtain an upper housing; and

fitting the upper housing in a lower housing on which the rotary shaft having the magnetic characteristic change portion is mounted.

4. The method according to claim **1**, further comprising the steps of:

cooling off a die assembly that includes the base die, the other dies and the centering rod after molding the resin; and

then removing the base die, the other dies and the centering rod to obtain an upper housing; and

fitting the upper housing in a lower housing on which the rotary shaft having the magnetic characteristic change portion is mounted.

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